A Study of the Use of Milk Replacers for Dairy Calves in the United States

A. J. HEINRICHS,[1] S. J. WELLS,[2] and W. C. LOSINGER
Centers for Epidemiology and Animal Health
USDA, Animal Plant Health Inspection Service
Veterinary Services
Fort Collins, CO 80521

ABSTRACT

This study focused on aspects of the National Dairy Heifer Evaluation Project that involved neonatal feeding practices and types of milk replacers utilized on dairy farms. Types of milk replacers and the management practices associated with their feeding were studied. Nearly 60% of US dairy farms use milk replacers for some or all of the feeding program for neonatal calves. Regional differences existed in the types of liquid feeds and milk replacers fed to calves. Western producers fed less milk replacer, and western and northeast producers fed replacers with less total CP. Many characteristics of management utilized along with these products reflect accepted management and nutrition practices. During the study period from 1991 to 1992, 11.2% of replacers contained casein. A greater proportion of these were found in the West during the first 6 mo of the study, reflecting changes in the milk replacer formulations during that time.

(**Key words**: calves, milk replacers, National Dairy Heifer Evaluation Project)

Abbreviation key: **NDHEP** = National Dairy Heifer Evaluation Project.

INTRODUCTION

Various feeding and management practices on dairy farms can have profound impacts on overall mortality, morbidity, and growth of the young calf. Successful calf growth and health depends on the combination of many factors related to health, management, and nutrition of the neonate. A wide variety of liquid feed sources is available to nourish the calf once it has been fed first colostrum and transition milk (second and subsequent milkings after first colostrum). Fresh, frozen, or fermented colostrums are each excellent, inexpensive feedstuffs for calves (2, 8, 15, 20, 23). Whole and waste milks are excellent choices for calf feed and are economical under many conditions. Milk replacers are also a very good source of liquid feed for calves. They are often very economical (second to waste milk) and, in many situations, are more easily adapted to the labor and facility needs of calf-raising operations than either whole or waste milk (7, 9).

Because of the digestive limitations of calves <3 wk of age, ingredient formulation is critical to allow for adequate digestion, proper growth, and performance (26). Therefore, milk replacers must be formulated with ingredients processed for the underdeveloped digestive system of the young calf. Within a few weeks of age, the ability of the calf to digest various feedstuffs improves dramatically as its enzyme production increases and diversifies (1, 18).

The nutritional availability of protein and energy sources used for milk replacers is a key factor in determining the outcome of the feeding program based on the source of feed used (24). The influences of calf management and environmental interactions such as housing (19, 21, 22), environmental temperatures (21, 25), and calf age (1, 6, 8, 14, 29) have been studied. In addition, the effects of different feeding methods, such as the reconstitution temperature of the replacer (4, 5, 17), nipple versus pail feeding (29), and ad libitum versus restricted access to milk replacer (21, 27) all have fundamental impacts on calf growth and health.

Received October 24, 1994.
Accepted June 16, 1995.
[1]Department of Dairy and Animal Science, The Pennsylvania State University, University Park 16802.
[2]Reprint requests.

Usage of milk replacers in the US has been reported in various surveys over the past few years (10, 12). Fluctuation in usage likely reflects several economic factors within the dairy industry. Data show that the percentage of farms that used milk replacer all or part of the time varied from 72.4% in 1979, to 52.0% in 1983 (12), and 47.1% in 1987 (10).

Objectives of the present study were to survey usage of various types of milk replacers fed to US dairy calves and to determine management practices utilized in the feeding of these milk replacers on commercial dairy farms.

MATERIALS AND METHODS

The National Dairy Heifer Evaluation Project (**NDHEP**) of the USDA Animal Plant Health Inspection Service was based on a series of prospective and retrospective surveys in addition to measurements and samples collected on farms across the US (11). The study utilized a multiple-frame (list and area) sampling technique in cooperation with the USDA National Agricultural Statistics Service. All survey information was obtained via personal interview with the producer. During the NDHEP, information regarding the use of milk replacer and management practices was collected during a visit to each farm by a state or federal veterinary medical officer. For operations using milk replacers, the milk replacer or replacers routinely fed to calves from birth to 3 wk of age and from 3 wk of age to weaning were evaluated by inspecting the feed tag and asking questions regarding feeding management practices used in conjunction with the feedstuffs. An in vitro rennet coagulation test (3, 13) was performed on a sample of each reconstituted milk replacer used on the farms. This analysis showed whether casein was present in the form of skim milk or sodium caseinate if it had not been heat treated. A sample of whole milk was analyzed on each farm as a positive control.

The probability sample design used for the national milk replacer survey, as part of the NDHEP analysis, was such that inferences could be made for the national population of producers and dairy animals. The design involved sample selection by the USDA National Agricultural Statistics Service of dairy producers with 29 or more cows from the January 1, 1991 agricultural survey. Respondents to the first phase of the study, which focused on overall dairy management, were asked to participate voluntarily in the second phase, which focused on dairy heifer health and management. A further portion of the second phase of the NDHEP included producers that generally fed milk replacers to their calves. This analysis determined specific management practices regarding the use of these milk replacers. Probabilities of selection were accounted for in each stage of the analysis. All data were weighted and adjusted for nonresponses (30) to derive US population estimates. Population estimates and standard deviations for the population estimates were obtained using SUDAAN (28). Regional analyses were done using data from western (California, Colorado, Idaho, Oregon, and Washington), midwestern (Iowa, Illinois, Indiana, Michigan, Minnesota, Nebraska, Ohio, and Wisconsin), northeastern (Maine, New Hampshire, New York, Pennsylvania, and Vermont), and southeastern states (Alabama, Florida, Georgia, Maryland, North Carolina, Tennessee, and Virginia), and all statistical comparisons were done using SUDAAN (28). The t tests were done using the standard errors generated by SUDAAN. Significance was noted at $P \leq .05$.

RESULTS AND DISCUSSION

Figure 1 shows the types of liquid feeds that were fed to calves after colostrum during part or all of the liquid feeding period for all farms in the US. These data are from the first phase of the NDHEP with 1811 farms in the data field (11). Fresh or sour colostrum and whole milk were fed by a great majority of the producers for all or part of the time. Similar percentages of medicated milk replacer, mastitic milk, and antibiotic milk were fed by producers. A much smaller percentage of producers fed unmedicated milk replacer. In addition to liquid feeds, calf starter was fed to 91.2% of calves prior to weaning. Hay was the most commonly fed forage, and small percentages of calves were fed fermented forages prior to weaning. Figure 1 does not show the percentage of time that each of these feeds were used on the farms. Data obtained from the ingredient composition of the milk replacer

labels showed that, on average, medicated replacers contained 21.3% CP (SE = .1), and unmedicated replacers contained 20.9% CP (SE = .1).

Results of analysis of feed sources given to preweaned calves after 24 h of age, grouped by number of preweaned calves on the farm at the start of the survey, are shown in Table 1. Mean herd sizes (55.6 cows) were smaller than the national average (11) for the group with 0 to 5 preweaned calves, near the average (75.9 cows) for the farms with 5 to 15 preweaned calves, and larger than the average (274 cows) for the group with >16 preweaned calves on the farm. A higher percentage of large farms fed whole, mastitic, and antibiotic milks to preweaned calves. Milk replacer and colostrum were not fed as often on these larger farms. The economy of farm size likely created a situation in which waste milk was more economical and manageable to use. In addition, calves on larger farms were weaned at older ages than those on smaller farms (10, 11). Larger farms purchased less milk replacer for preweaned calves, possibly because they were likely to have an alternate feed source available that would otherwise be a waste product. Also, different systems of management may necessitate longer liquid feeding periods for calves. No interactions were observed among regions for the data presented in Table 1.

In the third phase of the NDHEP study, operations that specifically fed milk replacers for all or part of the year to some or all calves are shown in Table 2 and are utilized in all subsequent tables. The data were collected by the age categories of birth to 3 wk of age and 3 wk of age to weaning, because likely physiological differences would necessitate different management practices for these periods (23). Overall, operations that used some medicated milk replacers used them 59.6 and 70.7% of the time and used unmedicated replacers 10.6 and 14.0% of the time for calves from birth to 3 wk of age and from 3 wk of age to weaning, respectively. Lower percentages of medicated replacers were used in the western and midwestern regions for younger calves and in the West for older calves. Producers in the Southeast fed less whole milk to calves of both

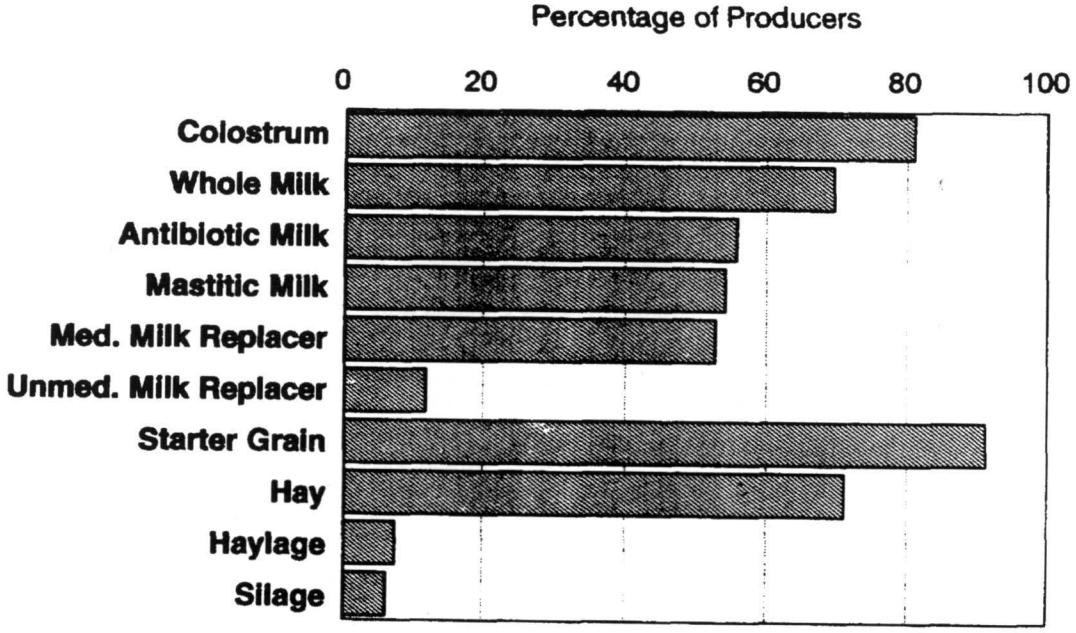

Figure 1. Types of liquid feeds fed to calves all or part of the time from birth to weaning. Med. = Medicated; unmed. = unmedicated.

TABLE 1. Percentage of producers feeding various liquid feeds and calf age at weaning.

	Preweaned calves[1]							
	0 to 5		6 to 15		≥16		Total	
Source of feed	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Whole milk	67.7[b]	3.2	66.5[b]	3.4	77.3[a]	3.5	68.2	2.0
Colostrum	80.8[a]	2.6	85.3[a]	2.6	72.2[b]	4.8	81.5	1.7
Medicated milk replacer	53.3[a]	3.5	56.4[a]	3.6	36.67[b]	4.2	52.7	2.3
Unmedicated milk replacer	12.7	2.2	10.4	2.1	15.4	3.2	12.2	1.4
Total milk replacer	64.0[a]	3.4	64.9[a]	3.5	51.4[b]	4.5	63.1	2.2
Mastitic milk	44.4[c]	3.4	59.0[b]	3.7	77.5[a]	3.3	53.2	2.4
Antibiotic milk (sick cow)	46.4[c]	3.4	61.1[b]	3.6	80.7[a]	3.0	55.4	2.4
Age at weaning, wk	7.5[c]	.2	8.1[b]	.2	9.2[a]	.2	7.9	.1

[a,b,c]Means within the same row with different superscripts differ ($P \leq .05$).

[1]Number of preweaned calves on the farm at the time of the survey.

age groups. Mastitic and antibiotic milks were used more in the West than in other regions of the US. Regional differences were generally similar for the types of feeds fed between age group categories. Differences between regions did not appear to be reflective of herd sizes.

Management factors used in conjunction with milk replacer feeding on US farms are shown in Table 3. The majority of producers fed ≥1.9 L of replacer for both age groups during one feeding, and milk was fed twice per day individually on nearly all farms. Over 93% of the producers mixed milk replacers using warm or cold water, as instructed by the manufacturer; 95% mixed only enough milk replacer for one feeding at a time, and none mixed replacer for more than a day at a time. In general, these practices indicate good management that is consistent with current recommendations; an exception to this,

TABLE 2. Percentage of liquids fed to dairy calves by region of the US for two age groups of dairy calves using some or all milk replacer.

	West		Midwest		Northeast		Southeast		Total	
	0 to 3 wk									
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Whole milk	17.0[a]	3.4	9.1[b]	1.6	10.2[ab]	2.1	3.7[c]	.9	9.2	1.1
Colostrum	11.0[b]	1.4	14.6[a]	.7	11.8[ab]	1.5	13.5[ab]	1.4	13.7	.6
Mastitic milk	6.4[a]	1.6	4.0[ab]	.6	2.4[b]	.7	4.9[ab]	2.0	3.8	.5
Antibiotic milk	7.8[a]	1.7	2.7[b]	.4	2.9[b]	.8	3.1[b]	.7	3.0	.3
Unmedicated milk replacer	11.0	4.6	11.6	2.1	8.6	2.2	7.9	2.7	10.6	1.9
Medicated milk replacer	46.8[b]	5.3	58.0[ab]	2.6	64.2[a]	3.3	66.8[a]	3.9	59.6	1.9
	3 wk to weaning									
Whole milk	6.7[ab]	2.3	4.4[ab]	1.1	7.5[a]	1.8	3.0	.8	5.1	.9
Colostrum	2.7	.8	2.0	.6	2.1	.9	3.4	.9	2.2	.4
Mastitic milk	10.5[a]	1.8	4.7[b]	.7	3.0[b]	.8	4.9[b]	1.9	4.6	.5
Antibiotic milk	11.0[a]	1.8	3.5[b]	.5	2.2[b]	.5	2.6[b]	.6	3.4	.3
Unmedicated milk replacer	17.8[a]	5.8	14.9[a]	2.6	12.3[a]	2.7	8.6[a]	3.0	14.0	1.8
Medicated milk replacer	50.1[c]	5.4	70.4[b]	3.0	73.0[b]	3.4	77.5[a]	3.9	70.7	2.2

[a,b,c]Means within the same row with different superscripts differ ($P < .05$).

however, was that at least 65% of operations were in cold environments and did not feed additional milk replacer to calves during winter or colder periods. Water availability to calves after feeding showed that fewer than half (44.7%) of the producer operations offered water to calves ≤3 wk of age, and 58.2% offered water to calves >3 wk of age after feeding. Few producers offered water within 10 to 30 min after feeding milk replacer to each age group (data not shown). Data previously reported (11) demonstrated that a large percentage of farms did not offer water for ad libitum consumption to calves before weaning. This practice is of particular importance when producers limit liquid intake while encouraging dry grain intake and may delay DMI to achieve adequate early weaning. This study did not determine whether added water was fed in the milk replacer before weaning.

Ingredient listings were obtained from feed tags collected on the farm. Variations in milk replacer formulations, as demonstrated by CP guarantee and rennet clot formation, are summarized in Table 4. More than half (56.3%) of the replacers used on the farms contained ≥22% CP, as recommended by the NRC (16). Almost all (97.3%) replacers contained the recommended ≥10% fat (16). Guaranteed CP percentages were different by region, but not by time, for protein levels only. Significantly more of the milk replacers used in the Midwest and Southeast contained ≥22% CP. This finding strongly suggests that different companies or nutrient specifications are used for these regions.

Analysis of the rennet clot test combined no clots and soft clots for calves from birth to 3 wk of age. No clot and soft clots were separated for the period of 3 wk of age to weaning, and both the medicated and unmedicated replacers were combined. Replacers used for both groups were virtually identical to the replacers fed at 3 wk of age to weaning. For the replacers fed from 3 wk of age to weaning, 10.2% formed either a soft or firm clot. Soft clots can be obtained from milk replacers containing as little as 5% of the CP derived from casein, and firm clots can be obtained from

TABLE 3. Management practices related to milk replacer usage in the National Dairy Heifer Evaluation Project.

Item	Age			
	0 to 3 wk		3 wk to weaning	
	$\bar{X}$	SE	$\bar{X}$	SE
Amount fed at each feeding, L				
<1.9	18.8	2.2	9.8	1.6
1.9 to 2.8	76.1	2.5	. . .	. . .
>2.8	5.2	1.4	. . .	. . .
>1.9	. . .	. . .	90.2	1.6
Times fed, no./d				
≥3 or free choice	1.5	.7	1.9	.8
2	97.9	.7	96.5	1.0
1	.6	.2	1.6	.6
Calves fed individually				
Yes	97.8	.7	96.1	.8
No	2.2	.7	3.9	.8
Temperature of water used				
Warm to cold if instructed on label	93.2	.7	96.1	.8
Cold when warm should be used	.7	.5	1.2	.7
Hot	6.1	1.2	5.6	1.1
More replacer fed during winter				
Yes (or warm climate year-round)	35.1	3.0	34.1	2.6
No	64.9	3.0	65.9	2.6
Time between feeding milk replacer and offering water, min				
<10	44.7	3.1	58.2	2.7
>30	54.6	3.1	40.1	2.7

TABLE 4. Variation in milk replacer formulation as demonstrated in CP percentage guarantee and ability to form a rennet clot.[1]

			Rennet coagulation					
	CP >22%		No clot		Soft clot		Firm clot	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Region								
West	36.0[b]	6.4	83.8	5.3	7.4	4.1	8.8[a]	3.6
Midwest	61.4[a]	4.0	89.4	2.6	8.5	2.4	2.2[ab]	1.2
Northeast	42.1[b]	5.3	93.3	2.6	6.4	2.6	.3[b]	.3
Southeast	69.0[a]	5.6	86.4	6.2	10.8	5.9	2.8[ab]	2.0
Quarter								
1	59.7	4.9	81.6[b]	4.2	13.6[a]	3.7	4.9[a]	2.3
2	55.3	6.0	88.0[ab]	4.6	11.6[ab]	4.6	.4[ab]	.3
3	56.8	6.5	96.8[a]	1.2	1.8[c]	1.0	1.4[ab]	.7
4	52.5	5.7	96.9[a]	2.4	2.9[bc]	2.4	.2[b]	.1
Overall	56.3	3.0	89.8	1.9	8.1	1.3	2.1	.9

[a,b,c]Means within columns with different superscripts differ ($P \geq .05$).

[1]Data based on milk replacers fed 3 wk of age to weaning.

those replacers containing greater percentages of the CP from casein (3, 13).

A breakdown of the data in Table 4 shows that a greater percentage of the milk replacers that formed clots were from the West, followed by the Southeast and Midwest. Less casein was found in replacers from the Northeast. Analysis of the data showed similar percentages of clotting replacers from each state within each region. Significantly greater percentages of replacers sampled during the first 4 mo of the study formed clots than did replacers sampled during the last period, indicating that ingredient changes were made in the formulation of replacers used during this period. This formulation shift can be observed in analysis of soft and firm clots. The majority of the milk replacers tested in the second half of the study contained no casein.

CONCLUSIONS

Milk replacers are fed to slightly more than half of the dairy calves in the US. There are regional differences in the usage of milk replacers, the nutrient specifications, and ingredients used in their manufacture. Farms with more calves use more waste, antibiotic, and whole milks to feed calves. Many of the management practices used in feeding milk replacers reflect accepted nutrition and management practices.

ACKNOWLEDGMENTS

The authors express sincere appreciation to Robin Reymann for her diligent efforts in the design and initial implementation of this study.

REFERENCES

1 Aranda, P., L. Sanchez, M. D. Perez, J. M. Ena, and M. Calvo. 1991. Insulin in bovine colostrum and milk: evolution throughout lactation and binding to caseins. J. Dairy Sci. 74:4320.

2 Campos, O. F., and J. T. Huber. 1983. Performance and digestion by calves from limestone added to milk replacers containing soy protein concentrate. J. Dairy Sci. 66:2365.

3 Emmons, D. B., and E. E. Lister. 1976. Quality of protein in milk replacers for young calves. I. Factors affecting in vitro curd formation by rennet (chymosin, rennin) from reconstituted skim milk powder. Can. J. Anim. Sci. 56:317.

4 Erickson, P. S., D. J. Schauff, and M. R. Murphy. 1989. Diet digestibility and growth of Holstein calves fed acidified milk replacers containing soy protein concentrate. J. Dairy Sci. 72:1528.

5 Fallon, R. J., F. J. Harte, and M. G. Keane. 1989. Methods of artificially feeding colostrum to the newborn calf. Ir. J. Agric. Res. 28:57.

6 Fayer, R., C. Andrews, B. L. Ungar, and B. Blagburn. 1989. Efficacy of hyperimmune bovine colostrum for prophylaxis of cryptosporidiosis in neonatal calves. J. Parasitol. 75:393.

7 Fowler, M. 1992. Recent calf milk replacer research update. XVII World Buiatr. Congr. Page 168 *in* Proc. XXV Am. Assoc. Bovine Pract. Conf., St. Paul, MN.

8 Hand, M. S., E. Hunt, and R. W. Phillips. 1985. Milk replacers for the neonatal calf. Vet. Clin. North Am. Food Anim. Pract. 1:589.

9 Heinrichs, A. J. 1994. A review of milk replacers for dairy calves. Comp. Contin. Educ. 16:1605.

10 Heinrichs, A. J., R. E. Kiernan, R. E. Graves, and L. J.

Hutchinson. 1987. Survey of calf and heifer management practices in Pennsylvania dairy herds. J. Dairy Sci. 70:896.

11 Heinrichs, A. J., S. J. Wells, H. S. Hurd, G. W. Hill, and D. A. Dargatz. 1994. The National Dairy Heifer Evaluation Project: a profile of heifer management practices in the United States. J. Dairy Sci. 77:1548.

12 Hoard's Dairyman. 1990. Continuing Market Survey. Hoard's Dairyman, Fort Atkinson, WI.

13 Jenkins, K. L. 1982. Effect of acid-precipitated casein in calf milk replacer on rennet clot. J. Dairy Sci. 65: 1652.

14 Leibholz, J., J. C. Radcliff, and J. A. Stewart. 1980. Minimal standards for dairy calf milk replacers. Aust. J. Dairy Technol. 35:66.

15 McGuirk, S. M. 1992. Colostrum: quality and quantity. XVII World Buiatr. Congr. Page 162 *in* XXV Am. Assoc. Bovine Pract. Conf., St. Paul, MN.

16 National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad. Sci., Washington, DC.

17 Noller, C. H., G. M. Ward, A. D. McGilliard, C. F. Huffman, and C. W. Duncan. 1956. The effect of age of the calf on the availability of nutrients in vegetable milk replacer rations. J. Dairy Sci. 39:1288.

18 Nousianinen, J. 1990. A high quality skim milk-whey-based milk replacer for calves. Brief Commun. Abstr. Posters XXIII Int. Dairy Congr. 1(Oct. 8–12): 57.(Abstr.)

19 Otterby, D. E., and J. G. Linn. 1981. Advances in nutrition and management of calves and heifers. J. Dairy Sci. 64:1365.

20 Peeters, J. E., I. Villacorta, E. Vanopdenbosch, D. Vandergheynst, M. Naciri, E. Ares-Mazas, and P. Yvore. 1992. *Cryptosporidium parvum* in calves: kinetics and immunoblot analysis of specific serum and local antibody responses (immunoglobulin A (IgA), IgG, and IgM) after natural and experimental infections. Infect. Immun. 60:2309.

21 Richard, A. L., L. D. Muller, and A. J. Heinrichs. 1988. Ad libitum or twice daily feeding of acidified milk replacer to calves housed individually in warm and cold environments. J. Dairy Sci. 71:2193.

22 Rindsig, R. B., and G. W. Bodoh. 1977. Growth of calves fed colostrum naturally fermented, or preserved with propionic acid or formaldehyde. J. Dairy Sci. 60. 79.

23 Roy, J.H.B. 1980. Factors affecting susceptibility of calves to disease. J. Dairy Sci. 63:650.

24 Schoonderwoerd, M., and V. Misra. 1989. Detection and quantitation of pea and soy derived proteins in calf milk replacers. J. Dairy Sci. 72:157.

25 Scibilia, L. S., L. D. Muller, R. S. Kensinger, T. F. Sweeney, and P. R. Shellenberger. 1987. Effect of environment temperature and dietary fat on growth and physiological responses of newborn calves. J. Dairy Sci. 70:1426.

26 Silva, A. G., J. T. Huber, and R. M. DeGregorio. 1986. Influence of substituting two types of soybean protein for milk protein on gain and utilization of milk replacers in calves. J. Dairy Sci. 69:172.

27 Sissons, J. W. 1989. Aetiology of diarrhoea in pigs and pre-ruminant calves. Page 261 *in* Recent Advances in Animal Nutrition. Butterworth Heinemann Ltd., London, England.

28 SUDAAN® User's Manual, Release 6.0. 1993. Professional Software for Survey Data Analysis. Res. Triangle Inst., ed. Research Triangle Park, NC.

29 Ternouth, J. H., J.H.B. Roy, and S. M. Shotton. 1976. Concurrent studies of the flow of digesta in the duodenum and of exocrine pancreatic secretion of calves. IV. The effect of age. Br. J. Nutr. 36:523.

30 United States Department of Agriculture. 1975 Scope and Methods of the Statistical Reporting Service. Stat. Rep. Serv. Misc. Publ. No. 1308. US Govt. Printing Office, Washington, DC.